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The Indirect Impact of Smallholder Vegetable Production on Children's Nutrition Outcomes in Rural Vietnam

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Childhood undernutrition, particularly stunting, wasting, and micronutrient deficiencies, remains a major health concern in rural Vietnam. While literature suggests leveraging agriculture to improve child nutrition via agricultural diversification, market engagement, and women's empowerment, very few studies have empirically explored how smallholder vegetable production can influence household nutrition. This paper examines the association of household-level vegetable diversity, market access, and market participation with nutrition outcome measures of children in smallholder households. We use a cross-sectional household dataset, collected in 2016 in northwest Vietnam, covering 234 children aged 6–60 months. We estimate and compare the results of regression models using three-stage least squares (3SLS), ordinary least squares (OLS), logistic regression, and seemingly unrelated regression (SUR), to explore variations in six nutrition outcome measures: height-for-age z-score (HAZ), weight-for-height z-score (WHZ), weight-for-age z-score (WAZ), stunting, wasting, and underweight. Our results suggest smallholder vegetable production has a significant indirect association with children's nutrition status via market participation. Market participation is an important factor in improving girls' HAZ and WHZ, and in reducing the probability of boys being stunted and underweight. The additional income from selling vegetables allows households to purchase nutritious food, which is likely to have a positive impact on children's nutrition outcomes.

Keywords: child nutrition, gender, market access, market participation, stunting, vegetable production, Vietnam, wasting

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INTRODUCTION

Vietnam has shown significant progress in reducing children's undernutrition in Southeast Asia [Association of Southeast Asian Nations (ASEAN) et al., 2016], but this has decelerated in recent years. The prevalence of stunting and underweight went down by 50 percent between 2001 and 2010 (Chaparro et al., 2014). However, between 2011 and 2015 there has been a relative increase in childhood stunting (from 23 to 25%) and wasting (from 4 to 6%) (Global Nutrition Report, 2022). Current interventions focus on the provision of key micronutrients, such as vitamin A, iron, and zinc (Chaparro et al., 2014), because children's undernutrition is due to micronutrient deficiencies arising from poor dietary intake and from infectious diseases like diarrhea [United Nations Children's Fund (UNICEF), 2013]. Current estimates indicate about 14, 29, and 52% of young children are vitamin A-, iron-, and zinc-deficient, respectively (Chaparro et al., 2014). However, declining financial support from the national and local governments for these activities, lack of strategic oversight and reduction of international aid, and the poor nutritional knowledge of mothers and other household members (Socialist Republic of Vietnam, 2012; IFPRI, 2016; Harris et al., 2021), have impeded progress. The positive impacts of these changes also differ between urban and rural areas, by region, and between the Kinh majority and ethnic minorities. Women, children, and ethnic minorities are the most vulnerable groups (National Institute of Nutrition and United Nations Children's Fund, 2011).

One way to lessen the financial burden of rural households is to promote agriculture and other existing production systems in locations with high populations of these vulnerable groups (Alderman et al., 2013). The agriculture sector therefore can play a crucial in combatting child undernutrition by addressing inadequate access to nutrient-rich food (Sharma et al., 2021). In Vietnam, many undernourished children are found in resource-poor households in rural areas dependent on agriculture for their main source of livelihood and nutrition (Linh and Glewwe, 2011).

Recent agriculture-nutrition projects have integrated a generalized theory of change, e.g., increasing production, income, women's empowerment, and/or nutrition knowledge to improve food security and dietary consumption, leading to improvements in nutritional status of target beneficiaries (Herforth and Ballard, 2016). At the household level, the pathway between agriculture and children's nutrition have been linked via the direct and indirect pathways: (1) household production of nutrient-rich agricultural products which may subsequently be consumed by the household members; and (2) market engagement where at least a share of the nutrient-rich agricultural products produced by the household are sold at markets generating agricultural income used to purchase diverse food products, or access to a wide variety of food due to market proximity (Dangour et al., 2012; Gillespie et al., 2012; Turner et al., 2013; Herforth and Harris, 2014; Kadiyala et al., 2014; Pinstrup-Andersen, 2014; Kanter et al., 2015; Sharma et al., 2021). In the direct pathway (pathway 1), the diversity and specific mix of agricultural crops cultivated by a household can influence household members' dietary quality and eventually nutrition. This is especially true for subsistence households that only consume what they produce (Muller, 2009). The indirect pathway (pathway 2) relates to how poor market access and low household incomes can be interrelated, and its effect on dietary diversity and nutrition. However, when households have increased market access and opportunities for market participation, they are faced with complex decisions about which agricultural crops to produce, consume and sell, and how to use any additional income generated from the sale of agricultural crops. Nevertheless, recent studies have highlighted the importance of market engagement because its effect on household nutrition has been found to be larger than agricultural diversity *per se* (e.g., Hirvonen and Hoddinott, 2017; Koppmair et al., 2017; Stifel and Minten, 2017), though much remains unknown about the impacts of market engagement and household vegetable production more broadly.

In addition to these pathways, other factors can also affect dietary diversity and, ultimately, child nutrition [Black et al., 2013; United Nations Children's Fund (UNICEF), 2013]. For instance, the role women play in resource-poor households affects the diets of household members (Alderman et al., 2013). As women tend to be more concerned with the health and well-being of children and other household members, their ability to control resources at home, to have access to credit, and to spend time selecting and preparing diverse and nutritious food for the family can have a strong, positive effect on household dietary quality, especially on children's diets (Quisumbing et al., 1995). Likewise, intrahousehold food allocation may be unequally distributed due to age and gender biases, and seasonal food shortages (Abdullah and Wheeler, 1985; Gittelsohn, 1991; Luo et al., 2001). Girls and women of reproductive age in certain countries in East and South Asia are often discriminated against when it comes to intrahousehold food allocation (Gittelsohn, 1991; Luo et al., 2001; Murphy et al., 2011; Madjdian and Bras, 2016; Rahman, 2018). In some rural villages in Bangladesh and the Philippines, children under 5 years old and/or women receive proportionately lower energy and protein intakes compared to the household's adult males (Abdullah and Wheeler, 1985; Senauer et al., 1988). In Indonesia, mothers consumed more carbohydrates than other family members (Wibowo et al., 2015). Girls and women of reproductive age in certain countries in East and South Asia are often discriminated against when it comes to intrahousehold food allocation (Gittelsohn, 1991; Luo et al., 2001; Murphy et al., 2011; Madjdian and Bras, 2016; Rahman, 2018). These associations are further influenced by other confounding factors like geography, ethnicity, education, maternal care practices, access to government supplementary feeding and immunization programs, WASH (water, sanitation and hygiene) practices, among others.

Vegetable consumption is a particularly sustainable way to combat some types of child undernutrition because of its micronutrient richness. However, its overall impact on child undernutrition remains largely unexplored. Most studies that have evaluated the impact of vegetables on nutritional outcomes were part of horticultural intervention programs (see review by Taren and Alaofe, 2013), which produced mixed findings (Masset et al., 2012; Ruel et al., 2013; Carletto et al., 2015).

This study therefore aims to fill this gap by examining the possible contribution of smallholder vegetable production on children's nutrition and identifying other significant factors. We investigate these relationships using pooled and gender-disaggregated samples. We incorporate four indicators of smallholder vegetable production in the standard empirical approach of examining child nutrition, controlling for the underlying child, maternal (including women's empowerment), and household characteristics.

We use cross-sectional data to study 234 children, aged 6–60 months, from 188 rural households in northwest Vietnam. We hypothesize that smallholder vegetable production has a positive effect on children's nutrition, which may occur either through a direct or indirect pathway. In the direct pathway, we specifically investigate whether diverse vegetable production is associated with childhood nutrition. The premise is that when households diversify their production, children also diversity their food intake accordingly, and therefore improve their diet, ultimately leading to improved nutrition. In the indirect pathway, we assess whether market engagement, via market access and market participation, positively correlate with nutritional outcomes. Households close to markets enjoy a wider array of diverse and nutritious foods that are not accessible to those in more remote rural areas. Similarly, the consumption of more diverse foods, leading to improved nutritional status, becomes possible because of income gains due to semi-commercialization (market participation). Understanding these direct and indirect pathways can help the Government develop long-term, sustainable solutions that are resource-efficient, and allow households to more effectively participate in.

MATERIALS AND METHODS

Study Area

The study was conducted in Lao Cai Province, a temperate vegetable-producing area in Vietnam's Northern Midlands and Mountainous region. It is an ideal research location for several reasons. Firstly, the province is among the poorest in Vietnam, with 22 percent of its population living below the poverty line (Lao Cai People's Committee, 2016). Secondly, the region is home to many ethnic minority communities, which are considered to be among the most vulnerable groups in the country (Kozel, 2014). They comprise 66 percent of the province's population: Mong (25%), Tay (15%), Dao (14%), Giay (5%), and Nung (4%) [General Statistics Office (GSO) of Vietnam, 2020]. Generally, they show preference for sons, due to their patriarchal and patrilocal clan system (Jones et al., 2014). Boys play significant cultural and economic roles, especially in religious rituals, in continuing the family heritage and in providing support to parents during old age (Jones et al., 2014).

Farming constitutes 93 percent of the economy in this region, especially in its rural areas (Linh and Glewwe, 2011). Many rural households grow vegetables only for their own consumption due to small landholdings [International Food Policy Research Institute (IFPRI), 2002]. Nevertheless, the province is suited to increasing vegetable intensification due to its climate and soil suitability (Wijk and Everaarts, 2007). In 2019, the province's total vegetable output was 11.74 tons per hectare [General Statistics Office (GSO) of Vietnam, 2020] compared to the country average of 16.82 tons per hectare [Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), 2022]. In spite of this, fruit and vegetable consumption comprise only 70 grams/capita/day [International Livestock Research Institute (ILRI), 2014], which is below the daily recommendation of 400 grams/capita/day (World Health Organization and Food and Agriculture Organization of the United Nations, 2005). In the province, diets are mainly composed of four food groups (cereals, vegetables, meat and poultry, and nuts and beans), which is lower than the national average of 10–11 food groups (Kim et al., 2021; Genova et al., 2022). Government nutrition programs have already been implemented in the province to overcome nutritional issues (Chaparro et al., 2014). However, among children under five, it still has one of the highest rates of stunting (31%) and underweight (18%) due to inadequate household food security (caused by poverty) and inadequate maternal and childcare (National Institute of Nutrition and United Nations Children's Fund, 2011; National Institute of Nutrition, 2019).

Fourthly, the region has the highest rates of child marriage (19%), where women marry before their eighteenth birthday [United Nations Population Fund (UNFPA) and United Nations Children's Fund (UNICEF), 2018]. Evidence shows that early marriages and premature childbearing can have a negative effect on maternal health (Goli et al., 2015), which can be transferred to her offspring (Parsons et al., 2015).

Lastly, many households are poor due to a "spatial trap"; i.e., their remoteness limits their access to resources like health, education, infrastructure and credit, and they may be isolated from both input and output markets (Epprecht et al., 2009; Dang, 2012; Kozel, 2014). Much of the land is considered sloping (**Figure 1**). This geographic diversity has resulted to ethnic minorities developing their own distinctive traditional farming systems, cultural practices, and indigenous knowledge that are well-suited to the environment in which they live in Tran (2003). This has also led to low agricultural productivity. Their strong adherence to cultural traditions versus acceptance of new agronomic technological innovations that offer opportunities to improve productivity and efficiency is a major factor to their poverty (Tinh, 2002; Bonnin and Turner, 2012).

Study Design

The authors gathered the data set analyzed in this study as part of an extensive rural household survey conducted in July-August 2016 and November 2016 in Lao Cai province, Vietnam. This study was part of a large project "Toward more profitable and sustainable vegetable farming systems in north-western Vietnam (AGB/2012/059)," funded by the Australian Centre for International Agricultural Research (ACIAR), aiming to improve the livelihoods of smallholder farmers in north-western Vietnam through market engagement and improved resource and disease-management practices. This study contributes to the broader aim of the ACIAR project by investigating whether there is a relationship between smallholder household characteristics and diets and nutritional outcomes. Ultimately, the goal of the research is to contribute information that may lead to programs and policies that address undernutrition among children in Lao Cai province, and improve livelihoods of the population in these remote areas in the long run.

Data was collected in two time periods to capture possible seasonal variations in both household consumption and household vegetable production. The survey sample included households from four districts (Bac Ha, Sa Pa, Muong Khuong, and Si Ma Cai). These districts were selected based on each having a mean elevation of 600 meters or more above sea level (masl) as temperate vegetable cultivation is best achieved at higher altitudes. **Figure 1** shows the administrative map of the province that is color-coded to indicate geographic heterogeneity.

Smallholder households were selected using a stratified multistage sampling strategy. Households had to be engaged in agricultural production (of any product, not just vegetables) during the past 3 years to qualify for the study. Communes in the four selected districts were grouped using the median elevation and median vegetable density per capita data. From the elevation and vegetable density per capita data, each commune was coded as either low elevation ($\leq$1,335 m) or high elevation

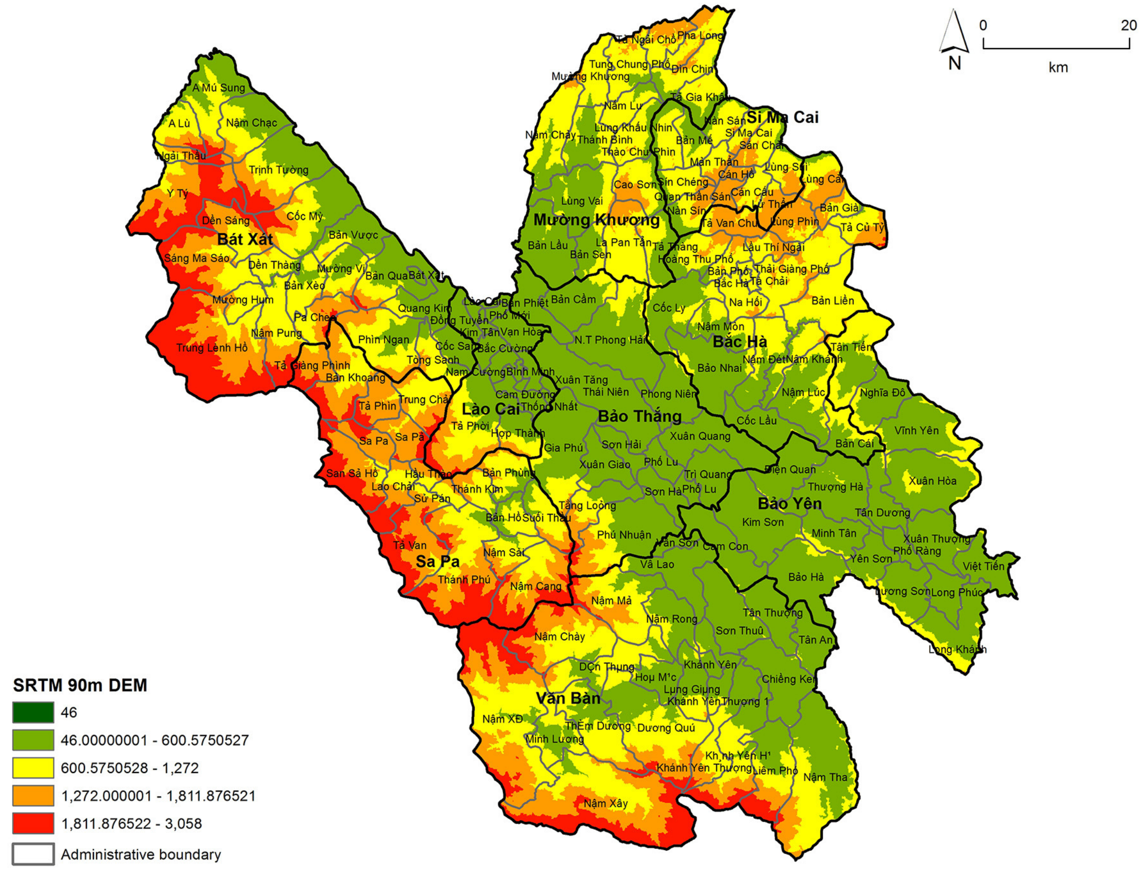

FIGURE 1 | Administrative map of Lao Cai province. Source: SRTM downloaded from http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp; Data: SRTM 90m digital Elevation Model (DEM) using ArcGIS10 http://srtm.csi.cgiar.org/SELECTION/listImages.asp.

(>1,335 m), and low vegetable density per capita (≤98) or high vegetable density per capita (>98). Then, communes were categorized into four strata: low vegetable density per capita-low elevation (LV-LA); low vegetable density per capita-high elevation (LV-HA); high vegetable density per capita-low evaluation (HV-LA); and high vegetable density per capita-high elevation (HV-HA). Finally, three communes in each stratum and four villages per commune were randomly selected[1]. In each village, ten households were randomly selected from a list of households provided by the rural commune (*xã*)/commune-level town (*thị trấn*) administrative officers, yielding 510 households from 51 villages in 13 communes.

Data

Our analyses focused on households with children aged 6–60 months. Detailed information on household and individual characteristics—including anthropometric measurements, intrahousehold food consumption, food choice and dietary beliefs, women's empowerment (using the modified Abbreviated-Women's Empowerment in Agriculture Index or A-WEAI Malapit et al., 2017), micronutrient supplementation and maternal nutritional knowledge, WASH practices, household income and expenditure, farm production and marketing activities in the last production cycle, and child health— were collected. Except for the women's empowerment module, the person primarily responsible for food preparation in the household was the target respondent, which in most cases is the child's mother. The modified A-WEAI module was administered to both the principal and secondary decision-makers in the household (normally, the parents of the child).

The semi-structured questionnaire was translated into Vietnamese by two native Vietnamese speakers and was validated by the Mekong Development Research Institute (MDRI)[2]. Pre-testing was done in the study areas in March, June, and July 2016. The paper-based questionnaire was transferred to a mobile application (CommCare[3]). A detailed Training Manual was provided to a team of 22 enumerators and five field supervisors from MDRI who facilitated the survey implementation. The team included one local enumerator fluent in the local Mong

[1]We purposely included one commune and three villages in Sa Pa district to be of some benefit to the project which funded this research.

[2]MDRI is a research institute in Hanoi, Vietnam that was contracted to assist our team in gathering data in the northwest.

[3]https://www.dimagi.com/commcare/

dialect. Enumerator training was conducted over a week and modifications were made to the survey instrument.

Anthropometric Measurements

Children were measured using the anthropometric protocol from the National Health and Nutrition Examination Survey (NHANES) Anthropometry Procedures Manual [Centers for Disease Control and Prevention (CDC), 2016]. The seca® 210 infantometer was used to record the recumbent length of infants and children up to 3 years who cannot stand on their own. The height of older children was measured using a tape measure[4]. The Laica® digital weight scale was used to record children's weight. The weight of infants and young children unable to stand independently was recorded with the aid of the mother. The mother and the child were weighed together, and then the mother's weight was deducted to derive the child's weight. Mothers were requested to remove their and their children's, shoes, hats, and heavy clothing, prior to the height and weight recording.

Using the 2006 WHO Child Growth Standards and the Stata user-written program zscore06 (Leroy, 2011), children's height and weight were converted into z-scores: height-for-age z-score (HAZ), weight-for-height z-score (WHZ), and weight-for-age z-score (WAZ). Three additional variables were created to measure the prevalence of stunting, wasting, and underweight, using the HAZ, WHZ, and WAZ, respectively. WAZ is a composite measure of HAZ and WHZ, and is difficult to interpret. However, it is commonly used to monitor growth and changes in malnutrition over time (O'donnell et al., 2008). Underweight is therefore used as a summary indicator, reflecting a child being stunted or wasted (Kimenju and Qaim, 2016). Children with missing data on height, weight, age, and gender were excluded from our analyses. The observed standard deviations of the z-scores can also identify inaccurate data due to measurement or coding errors. Therefore, we followed the WHO cut-off points for each of the child nutrition outcomes to identify these errors and exclude children whose values are in these ranges: HAZ, $\leq$-6 or $\geq$6 SD; WHZ, $\leq$-5 SD or $\geq$5 SD; and WAZ, $\leq$-6 or $\geq$5 SD [World Health Organization (WHO), 2010b].

Econometric Model Specification

We adopt the conceptual framework commonly used to explain the causes of child undernutrition [Black et al., 2013; United Nations Children's Fund (UNICEF), 2013]. In this framework, poor diets and diseases are the immediate determinants of child undernutrition. These factors, which often occur together, are caused by several underlying factors, like lack of access to food, either physically or economically, poor maternal and child-care practices, and an unhealthy home environment, due largely to income poverty.

The empirical model estimated is shown in equation (1):

$$H_{ijh} = constant + \beta VegDiversity_h + \gamma Market_h + \delta' \mathbf{G}_h + \omega' \mathbf{CH}_i + \sigma' \mathbf{M}_j + \varphi' \mathbf{HH}_h + \varepsilon_{ijh} \quad (1)$$

where $\boldsymbol{H_{ijh}}$ is one of the six alternative nutrition outcome measures: *HAZ*, *WHZ*, *WAZ*, *stunting*, *wasting*, and *underweight* of child i of mother j in household h. The *HAZ*, *WHZ*, and *WAZ* are continuous variables, and the prevalence of *stunting*, *wasting*, and *underweight* are binary variables. $\boldsymbol{G_h}$, $\boldsymbol{CH_i}$, $\boldsymbol{M_j}$, and $\boldsymbol{HH_h}$ are vectors of women's empowerment/adequacy, child characteristics, maternal characteristics, and household features, respectively; and ε is the error term. In these models, we focus on the estimates of β and γ, which indicate whether our main variables of interest have positive, negative, or no effects on the specific nutrition outcome measure. The main variables of interest and specific controls used in the model are explained subsequently.

We hypothesize that smallholder vegetable production may have a positive relationship with children's nutrition. The link between household vegetable production and children's nutrition could be a result of either consumption from household production (direct), or consumption of more diverse foods due to market access and/or higher income gained from market participation (indirect) (e.g., Carletto et al., 2015; Kanter et al., 2015). We measure the association of smallholder vegetable production and children's nutrition outcomes using four main variables of interest: *VegDiversity*, *TimeMarket*, *TradMarket*, and *ModMarket*.

$VegDiversity_h$ is a measure of household vegetable production diversity, and is a simple unweighted count of the number of unique vegetables cultivated by household *h* in the last 12 months prior to July/August 2016 (Keding et al., 2012). $VegDiversity_h$ was assessed by asking the respondent about the types of vegetable cultivated for home consumption, for market, lost due to postharvest spoilage, given as gift to neighbors or used for seed storage. We hypothesize that greater diversity in vegetable production can improve dietary quality and, eventually, nutrition through the subsistence pathway (Sibhatu and Qaim, 2017).

Recent studies have also pointed to the importance of markets ($Market_h$) on children's nutritional status, in terms of both access and market participation (e.g., Hirvonen and Hoddinott, 2017; Stifel and Minten, 2017). In this case, we include *TimeMarket* to indicate market access, and *TradMarket* and *ModMarket* to indicate market participation. *TimeMarket* is the one-way travel time in hours to the nearest food market. We have added this variable to differentiate remote rural households from those in closer proximity to food markets. We hypothesize that closer proximity to food markets allows children to have more diversified food intake, which may explain improvements in the nutritional status of children living closer to markets as compared to children who are residing in remote areas (Abay and Hirvonen, 2016). We impute the missing values and "don't know" responses with the mean of the village, commune, or the district, depending on which is available, by transport type. Two binary variables indicate market participation in the last production cycle: if they have sold to traditional channels (*TradMarket*), and to modern channels (*ModMarket*). Traditional channels are the local market in the village/commune/district, selling to fellow farmers, and selling to collectors that visit the farm(s). Modern market channels include supermarkets, wholesale markets, cooperatives, and other retailers in Hanoi and other nearby

[4] A tape measure is a retractable flexible ruler that is used to measure length or distance.

provinces. For these two binary variables, our hypothesis is that market participation positively affects children's nutritional status through the income gained from semi-commercialization, allowing the household to purchase more diversified food, thus promoting better nutritional status.

We also control for women's empowerment/adequacy (G_h) since previous studies suggest that women's empowerment has been a significant predictor of children's nutritional status. Women are normally more health-promoting than men through the preparation of more nutritious and healthier food, and through childcare (Quisumbing et al., 1995). For instance, in Burkina Faso, improvements in women's empowerment (spousal communication, purchasing decisions, healthcare decisions, and family planning decisions) contributed to the program's impact on reducing wasting (Heckert et al., 2019). A recent study also found positive association between women's empowerment and gender equality with child HAZ using the Feed the Future population-based survey data from Bangladesh, Cambodia, Ghana, Mozambique, and Tanzania (Quisumbing et al., 2021). In this study, two binary variables, which are adopted from the A-WEAI indicators, are used to control for women's empowerment/adequacy: woman make decisions on household income (*Income*), and woman's workload is less than the time poverty line of 10.50 h (*Workload*). Each indicator is assigned a value of 1 if the woman's achievement is adequate, i.e., it exceeds the defined inadequacy cut-off for the specific indicator, and a value of 0 if otherwise (Malapit et al., 2017). *Workload* indicates reduced workload, which could indicate better maternal care through mothers having sufficient time to make healthier decisions about their children's food intake, grooming, and sanitation (Cunningham et al., 2019).

CH_i are child-related covariates that include dietary diversity (*DDS*), age (*AgeChild*); and binary variables for male child (*MaleChild*) and incidence of diarrhea in the 2 weeks prior to the interview (*Diarrhea*). *DDS* is defined as a simple unweighted count of the number of unique food groups consumed by the child in each reference period. In this study, the *DDS* ranges from 1 to 14, and is based on the 14 food groups in the Vietnamese Food Composition Table 2007 edition[5]: cereal and products; starchy roots and tubers; nuts and beans; vegetables; fruits and berries; oils, fats and butters; meat, poultry game and its products; fish, shellfish, and products; eggs and products; milk and milk products; canned products; sugars, preserves and confectionery; soft drinks and other beverages including alcoholic drinks; and spices and sauces. The derivation of the *DDS* considers all food items consumed by the child in each reference period. These food items are classified three ways: (a) home-cooked meals; and food sourced elsewhere, either purchased or provided by relatives and/or neighbors, composed of (b) cooked meals, and (c) specific food items (uncooked) that were directly consumed by children, e.g., bread, branded milk, fresh fruits and raw vegetables, candies, chips, and juices. *DDS* is the mean Dietary Diversity Score of the child in three reference periods. We include *Diarrhea* since it has been shown to negatively impact on children's nutritional outcomes, especially WHZ and wasting [World Health Organization (WHO), 2010a].

M_j are maternal covariates that include age (*AgeMother*), education (*EducMother*), height (*HtMother*), body mass index (*BMIMother*), and a binary for Mong ethnicity (*MongMother*). *EducMother* was highly correlated with the nutritional knowledge of the mother so we treat it as proxy for better child-care practices and greater maternal nutritional knowledge (Alderman and Headey, 2017). A mother's height indicates her genetic endowment; women who are stunted are likely to have stunted offspring (Addo et al., 2013; Forero-Ramirez et al., 2014; Prendergast and Humphrey, 2014; De Onis and Branca, 2016; Wu et al., 2021). We also included BMI because it has been shown to effect the likelihood of child stunting (Headey et al., 2012).

HH_h are household-level covariates that include geographic stratum to which the village belongs to according to elevation and vegetable per capita density[6] (*LV-LA*, *LV-HA*, *HV-LA*, and *HV-HA*), number of children <5 years old (*CHD5b*), total cultivated area (*Area*), monthly non-food expenditure per capita (*NonFoodExp_pc*), and a binary variable for access to improved toilet facility (*ImprovedToilet*). The geographic stratification was included to control for geographical differences affecting vegetable production due to elevation or other factors. *CHD5b* is a proxy for the mother's ability to undertake good child-care practices. The more infants and younger children in the household, the more time constrained the mother is as she juggles childcare and other household (including agricultural) activities (Babu et al., 2014). *Area* is a control for farm-specific characteristic, while *NonFoodExp_pc* and *ImprovedToilet*[7] are proxies for household income and good sanitation, respectively.

Empirical Strategy

We first estimate equation (1) using ordinary least-squares (OLS) regressions for the three continuous nutrition outcome variables (*HAZ*, *WHZ*, and *WAZ*) and Logit regressions for the three binary outcome variables (*stunting*, *wasting*, and *underweight*) to assess the empirical relationship between children's nutritional outcomes and smallholder vegetable production. We present the marginal effects for the Logit estimations. In both estimators, robust standard errors are used and are clustered at the household level.

Three of our main variables of interest— *VegDiversity*, *TradMarket* and *ModMarket*— are potentially endogenous. This renders the OLS and Logit biased and inconsistent estimators. Using Wooldridge's robust score chi^2 and robust regression-based F-test for exogeneity[8], we find that, in some of the

[5]The food groups in the 1994 and the 2007 versions of the Vietnamese Food Composition Tables are similar, except that the ordering of food group "softdrink, beverages, alcoholic beverages (13)" and "condiments and traditional sauces (14)" are interchanged.

[6]L=low, H=high, A=altitude/elevation, V=vegetable per capita density.

[7]Improved toilet facilities include: septic tank, biogas, double pit dry, ventilated pit dry, and single pit dry; unimproved toilets include no toilet, pour flush, fishpond, and ashes/bridge/bucket (World Health Organization and United Nations Children's Fund, 2006).

[8]Instead of the Durbin Wu-Hausman statistics for endogeneity test, Wooldridge's (1995) robust score test and robust regression-based test statistics are reported after 2SLS estimation with a robust VCE (Wooldridge, 1995 as cited by StataCorp, 2017).

models, endogeneity exists with *TradMarket* and *ModMarket*, and hence the instrumental variable (IV) method is preferred. Therefore, we use the percentage of surveyed neighbors in the village selling to traditional channels, excluding the household (*PctNeighborTrad*) as an instrument for *TradMarket*; and the percentage of surveyed neighbors in the village selling to modern channels, excluding the household (*PctNeighborMod*) for *ModMarket*. The use of the percentage of neighbors selling to traditional channels excluding the household (*PctNeighborTrad*) is a good instrument for *TradMarket* since a household selling to *TradMarket* is likely to have neighbors similarly engaged in selling to *TradMarket* (Andersson et al., 2015). The same can be said for *PctNeighborMod*.

Mathematically, we model them as follows:

$$VegDiversity_h^V = \beta_0^V + \beta_1^V Distance + \beta_2^V G_h + \beta_3^V CH_i + \beta_4^V M_j + \beta_5^V HH_h + \varepsilon_h^V \quad (2)$$

$$TradMarket_h^T = \beta_0^T + \beta_1^T PctNeighborTrad + \beta_2^T G_h + \beta_3^T CH_i + \beta_4^T M_j + \beta_5^T HH_h + \varepsilon_h^T \quad (3)$$

$$ModMarket_h^M = \beta_0^M + \beta_1^M PctNeighborMod + \beta_2^M G_h + \beta_3^M CH_i + \beta_4^M M_j + \beta_5^M HH_h + \varepsilon_h^M \quad (4)$$

Equations (2)–(4) form a system of equations that account for the endogeneity of *VegDiversity*[9], *TradMarket* and *ModMarket*. We use the three-stage least squares (3SLS) method in all six alternative nutritional outcome measures, which is robust to the application of instrumental variables (IV) in the seemingly unrelated regression (SUR), since error terms of the system of equations might be correlated. The application of linear regression when the dependent variable is dichotomous, in this case the three prevalence outcome variables (*stunting*, *wasting*, *underweight*), has been justified by Angrist and Pischke (2009) and Hellevik (2009). Since the error terms might be correlated between the system of equations for a specific child and be uncorrelated across children, the seemingly unrelated regression (SUR) models are also estimated. The Breusch-Pagan test of independence indicated statistically significant correlations between the error terms of the system of equations in all six alternative nutritional outcomes. Therefore, the main results of the 3SLS estimates are used for inference in the subsequent section, and are compared with OLS, Logit, and SUR estimates to determine the possible direction of the bias.

We use Stata v15.1 (StataCorp, College Station, TX) for the descriptive and statistical analyses. Analyses are done for the pooled sample and were gender-disaggregated to identify any differential effects for boys and girls.

[9]As part of a system of equations, we use distance to an agricultural office (*Distance*) as an instrument for *VegDiversity*. The use of *Distance* could be a good instrument of *VegDiversity*, since proximity to an agricultural extension office, which can be found in most communes, means easy access to information on improved crop production practices and free seeds, and has therefore the potential to affect *VegDiversity* (Di Falco et al., 2011).

RESULTS AND DISCUSSION

Descriptive Statistics

Our sample consists of 266 children aged 6–60 months from 210 households. After cleaning the data, the final number of observations with complete information is 234 children from 188 households. We have a nearly balanced sample of boys ($n = 123$) and girls ($n = 111$). **Table 1** provides the definition and summary statistics of all variables used in the analyses.

The main variables of interest comprise variables that measure vegetable production diversity (*VegDiversity*), market access (*TimeMarket*), and market participation (*TradMarket* and *ModMarket*). The mean *VegDiversity* is 3, and ranges between 0 and 13 vegetables. *TimeMarket* is 0.39 h on average, with the most remote household traveling for 1.50 h to access the market. Most of the households are involved in vegetable production, with 60 percent having sold to some type of market (44% to *TradMarket*, 20% to *ModMarket*, and about 5% to both traditional and modern channels).

More than 60 percent of woman decision-makers make decisions on *Income* and nearly 30 percent have a workload that is less than the time poverty line of 10.50 h per day (*Workload*).

The average age of young children in our sample is 37.40 months, and they consume food belonging to four food groups (*DDS*), on average. Seventeen percent of the 188 households indicate that some or all of their children have experienced diarrhea 2 weeks prior to the survey (*Diarrhea*).

Most mothers belong to the Mong ethnic group, and their average age is 41 years. The oldest is 87 years old, because the respondent is the child's grandmother; the biological mother is working elsewhere or has passed away, and the grandmother took over the mother's role. Mothers who are working and residing elsewhere are excluded since we only include household members staying in the house 4 days of the week or 6 months of the year. About 40 percent are illiterate, 22 percent have primary-level education, and 33 percent have reached secondary-level[10]. The average maternal height is 149.77 centimeters (cm), which is considered stunted following the definition of Addo et al. (2013) on maternal stunting as being below 150.10 cm. The mean BMI is 22.40 kilograms per square meter (kg/m^2), which is considered "normal" weight (WHO Expert Consultation, 2004).

The average number of children under 5 years old is two. We find high variability in the total cultivated land area (*Area*); the average is 1.08 hectares, and the largest land area is 19.60 hectares. Wide variation is also observed for *NonFoodExp_pc,* with the lowest monthly non-food expenditure per capita equal to 0.04 million VND[11] (US$1.72) and the highest is 13.88 million VND (US$598.06). The majority of households do not have access to a safe water source and drinking water, and only about 37 percent have access to improved toilet facilities.

[10]In the regression model, education is treated as a continuous variable rather than a categorical variable to determine the effect of higher education on the child nutritional outcomes.

[11]1 US Dollar (US$) = 23,208.37 Vietnamese Dong (VND) (2020 average). Source: UNCTAD, 'Currency exchange rates, annual, 1970-2020', http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx.

TABLE 1 | Descriptive statistics of key variables of children 6–60 months in Lao Cai province, Vietnam.

Variable	Description	Mean	SD	Min	Max
Outcome variables					
HAZ	Length/height-for-age z-score	−2.20	1.65	−5.91	6.00
WHZ	Weight–for–height z–score	−0.25	1.42	−0.99	4.93
WAZ	Weight-for-age z-score	−1.44	0.98	−4.72	1.62
Stunting	Prevalence of stunting (1 = stunted [HAZ <-2 SD], 0 = no)	0.62	0.49	0	1
Wasting	Prevalence of wasting (1 = wasting [WHZ <-2 SD], 0 = no)	0.09	0.29	0	1
Underweight	Prevalence of underweight (1 = underweight [WAZ <-2 SD], 0 = no)	0.24	0.43	0	1
Main variables of interest					
VegDiversity	Number of different kinds of vegetables produced at the farm in the last cropping cycle	2.95	1.79	0	13
TimeMarket	Travel time from residence to nearest food market (hour)	0.39	0.24	0.03	1.50
TradMarket	Household sold vegetables to traditional channels (1 = yes, 0 = otherwise)	0.42	0.50	0	1
ModMarket	Household sold vegetables to modern channels (1 = yes, 0 = otherwise)	0.20	0.40	0	1
Gender					
Income	Woman can make decisions on household income (1 = adequate, 0 = otherwise)	0.63	0.48	0	1
Workload	Woman's workload is less than the time poverty line of 10.50 h (1 = adequate, 0 = otherwise)	0.27	0.44	0	1
Child characteristics					
DDS	Mean Dietary Diversity Score of children aged 6–60 months	4.13	1.17	1	8.25
AgeChild	Age of young child (month)	37.40	14.39	6	60
MaleChild	Young child is male (1 = yes, 0 = otherwise)	0.53	0.50	0	1
Diarrhea	Some or all children experienced diarrhea in the last 2 weeks (1 = yes, 0 = otherwise)	0.17	0.37	0	1
Maternal characteristics					
AgeMother	Maternal age (year)	41.00	16.12	19	86.58
EducMother	Maternal education (categorical treated as continuous: 0 = no education, 1 = nursery, 2 = some primary, 3 = primary (completed all years), 4 = lower secondary, 5 = upper secondary, 6 = vocational, 7 = university/college, and 8 = postgraduate)	2.29	2.06	0	8
MongMother	Mother is Mong (1 = yes, 0 = otherwise)	0.76	0.42	0	1
HtMother	Maternal height (centimeter)	149.77	5.65	129	165
BMIMother	Maternal BMI (kg/m^2)	22.40	2.86	15.92	31.29
Household characteristics					
LV-LA	Commune is classified as low vegetable density per capita-low altitude area (1 = yes, 0 = otherwise)	0.19	0.39	0	1
LV-HA	Commune is classified as low vegetable density per capita-high altitude area (1 = yes, 0 = otherwise)	0.24	0.42	0	1
HV-LA	Commune is classified as high vegetable density per capita-low altitude area (1 = yes, 0 = otherwise)	0.29	0.45	0	1
HV-HA	Commune is classified as high vegetable density per capita-high altitude area (1 = yes, 0 = otherwise)	0.29	0.46	0	1
Child5b	Number of children 5 years old and below	1.50	0.66	1	4
Area	Total cultivated area (hectare)	1.08	2.03	0	19.60
NonFoodExp_pc	Monthly non-food expenditure per capita (million VND)	0.79	1.65	0.04	13.88
ImprovedToilet	Access to improved toilet (1 = yes, 0 = otherwise)	0.37	0.48	0	1
Household (number of households in sample)	188				
Observations (number of children in the sample)	234				

SD, "standard deviation"; Min, "minimum"; Max, "maximum"; BMI, "body mass index"; kg/m^2, "kilogram per square meter"; VND, "Vietnamese Dong"; %, "percent". Initially, we included access to safe water where safe water sources are piped water and tube well, and unsafe water sources are groundwater source and surface water. However, there was no variation (only 3% have access to safe water source) and, hence, it was dropped. Source: Vietnam Rural Household Survey (July–August 2016).

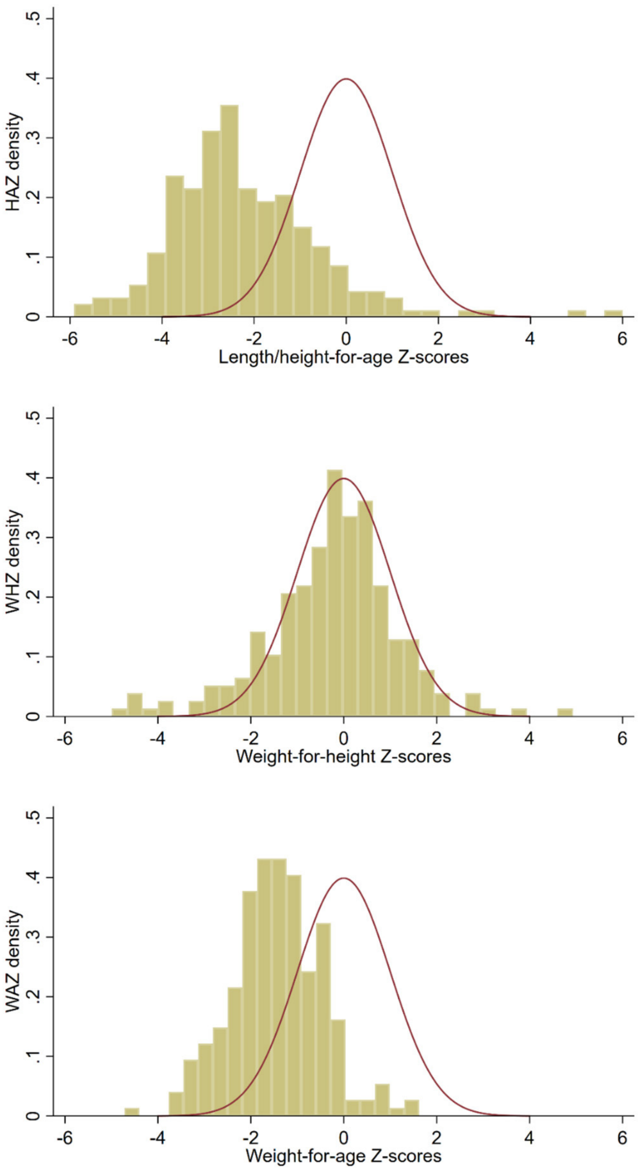

FIGURE 2 | HAZ, WHZ, and WAZ of sampled children in Lao Cai province. Note: WHO child growth standards are shown in standard normal densities. Source: Vietnam Rural Household Survey (July–August 2016).

The mean HAZ, WHZ, and WAZ are −2.20, −0.25, and −1.44 SD below the medians in the reference population, respectively (**Table 1**). **Figures 2**, **3** show the overall distribution for HAZ, WHZ, and WAZ, for the pooled sample and by gender, respectively. These figures further show the extent of stunting, where the majority of children have HAZ below the WHO child growth standards depicted as standard normal densities. In the pooled sample, 62 percent are stunted (HAZ <-2 SD), 9 percent are wasted (WHZ <-2 SD), and 24 percent are underweight (WAZ <-2 SD) (**Figure 3**). These estimates are higher than the 2019 provincial and regional averages (National Institute of Nutrition, 2019) and are consistent in each of the four districts. By gender, there are slightly more boys who are stunted (65%) and underweight (24%), and more girls who suffer from wasting (13%) (**Figure 3**). The higher prevalence of stunting among boys was also observed in several countries in Africa, which suggests that boys are more vulnerable to health inequalities than girls (Wamani et al., 2007; Thurstans et al., 2020).

Disaggregating them by age group, we find a higher incidence of stunting in the 24–60-month group, and a higher incidence of wasting in the 6–23-month group. The results for the children in the 6–23-month group may represent growth faltering, while those for the 24–60-month group may reflect the full impact of various postnatal issues (Alderman and Headey, 2018). We find more girls who are stunted (64%) and more boys who are wasted and underweight (20 and 28%, respectively) in the 6–23-month old age group. In the 24–60-month old age group, stunting (67%) and underweight (28%) are more prevalent among boys, and wasting is more prevalent among girls (27%). By geographic strata, stunting and underweight are highest in HV-LA (70 and 30%, respectively). In contrast, the lowest incidence of stunting and underweight are in HV-HA (49%) and in LV-LA (18%), respectively. In the subsequent analyses, results are presented for the pooled sample and disaggregated by gender, instead of by age group, due to small sample size.

Impact of Smallholder Vegetable Production on HAZ, WHZ, and WAZ

In the pooled sample, only market participation (*TradMarket* and *ModMarket*) is significantly associated with improvements in *WAZ* (**Table 2**, Panel 9). Households that sell to *TradMarket* benefit via a *WAZ* increase of 0.334 SD ($p < 0.10$). The association is larger and more significant when households sell to *ModMarket*, with a *WAZ* increase of 0.354 SD ($p < 0.05$). These associations are robust across different estimation methods (OLS and SUR).

By gender, *VegDiversity* and market participation (*TradMarket* and *ModMarket*) are significantly associated with *HAZ*, *WHZ*, and *WAZ*, especially for girls. *VegDiversity* is associated with a 1.134 SD increase in *HAZ* ($p < 0.05$) among girls (**Table 3**, Panel 7). However, it affects the *WHZ* (Panel 8) of girls and boys differently. For girls, a 1.201 SD decrease in *WHZ* ($p < 0.05$) is observed, while a 0.772 SD marginal increase ($p < 0.10$) is observed for boys. For market participation (*TradMarket* and *ModMarket*), significant associations were only found for girls, with larger coefficients and more significant positive effects of market participation on *HAZ* and *WHZ* ($p < 0.05$), and *WAZ* at the 5- and 10-percent levels of significance (Panels 7 to 9). The positive and significant association between *ModMarket* and *WAZ* is robust across different estimation techniques, similar with the findings in the pooled sample (**Table 2**, Panel 9). In particular, *ModMarket* is associated with a 1.115 SD increase in *HAZ* ($p < 0.05$), and a 0.487 SD increase in *WAZ* ($p < 0.10$). *TradMarket* is also associated with a 0.905 SD increase in *WHZ* ($p < 0.05$), and a 0.498 SD increase in *WAZ* ($p < 0.05$).

These results suggest that market participation does have a significant effect in improving the HAZ, WHZ, and WAZ

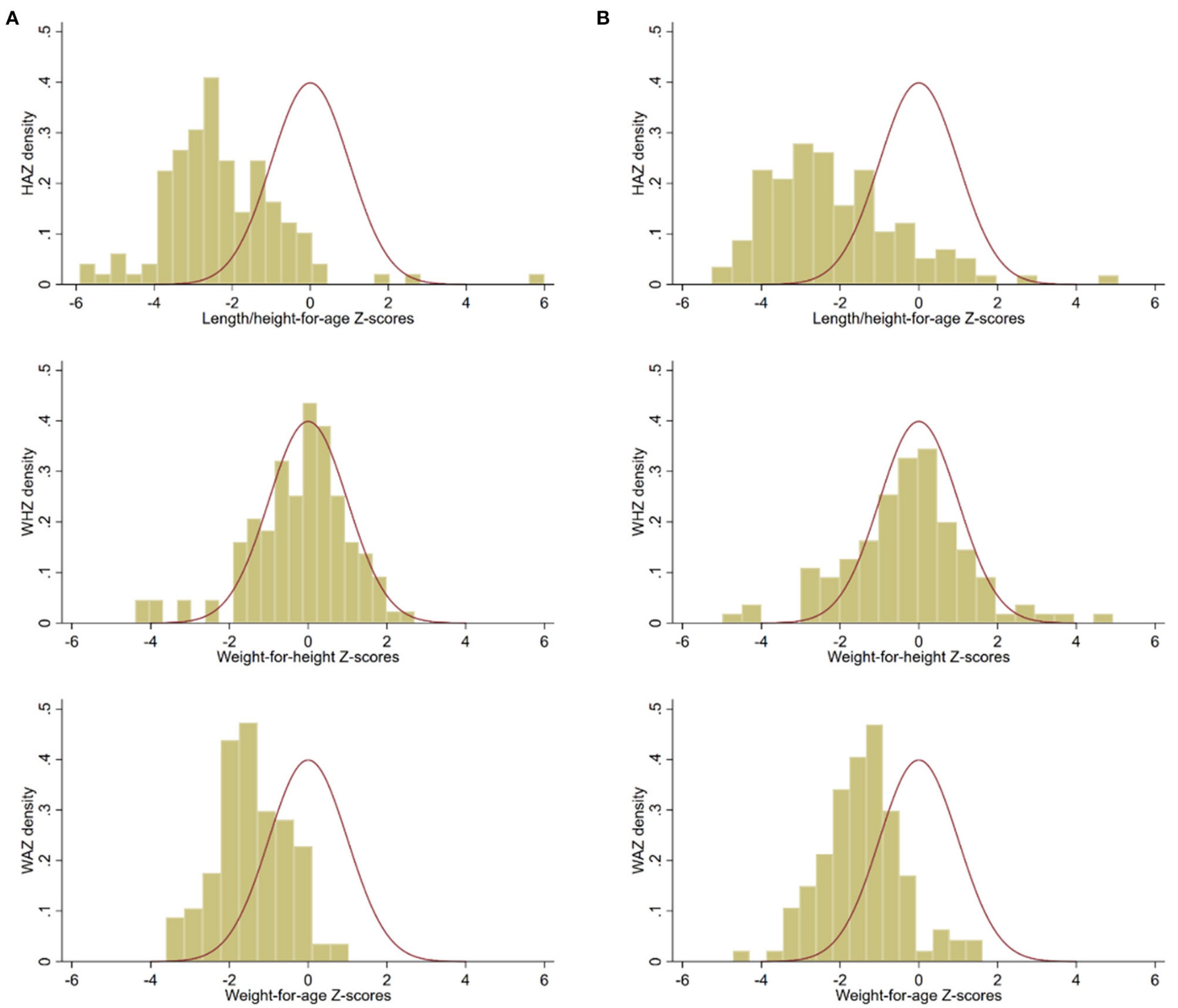

FIGURE 3 | HAZ, WHZ, and WAZ of sampled boys **(A)** and girls **(B)** in Lao Cai province. Note: WHO child growth standards are shown in standard normal densities. Source: Vietnam Rural Household Survey (July–August 2016).

of children in this province, especially among girls. Selling to traditional channels can improve the current WHZ. The effect is greater when households engage in modern market participation; it can positively affects children's linear growth (HAZ), an indicator of long-term undernutrition. Also, the link between vegetable production diversity and children's nutritional status should not be discounted. While its impact differs in HAZ and WHZ, what is crucial is that, like *ModMarket,* it is also associated with significant improvements in young girl's linear growth (HAZ). This has important implication for curbing the transmission of intergenerational linear growth retardation (Walker et al., 2015) in rural areas, as we find that a one unit increase in maternal height decreases the probability of stunting (**Table 4**, Panel 7, $p < 0.05$).

Impact of Smallholder Vegetable Production on the Prevalence of Stunting, Wasting, and Underweight

In general, *TradMarket* and *ModMarket* have implications for reducing the probability of *underweight* and *stunting*, respectively (**Table 4**, Panels 7 and 9). Increased *VegDiversity*, however, is associated with an increased probability of being *underweight* although the association is marginal (Panel 9).

By gender, *VegDiversity* and market participation (*TradMarket* and *ModMarket*) are significantly associated with *stunting*, *wasting*, and *underweight*, especially for boys. *VegDiversity*, while reducing the probability of *wasting* (**Table 5**, Panel 8), does not reduce the probability of *stunting* and *underweight* (Panels 7 and 9, respectively) among boys as

TABLE 2 | Impact of smallholder vegetable production on HAZ, WHZ, and WAZ of pooled sample.

Variables	Dependent variables and estimators: Z-scores (Pooled)								
	(1) HAZ OLS	(2) WHZ OLS	(3) WAZ OLS	(4) HAZ SUR	(5) WHZ SUR	(6) WAZ SUR	(7) HAZ 3SLS	(8) WHZ 3SLS	(9) WAZ 3SLS
Main variables of interest									
VegDiversity	0.006	−0.065	−0.037	0.018	−0.065	−0.037	0.117	0.015	0.141
	(0.062)	(0.056)	(0.044)	(0.068)	(0.059)	(0.040)	(0.368)	(0.316)	(0.218)
TimeMarket	0.252	0.178	0.252	0.282	0.178	0.252	0.272	0.180	0.269
	(0.459)	(0.411)	(0.250)	(0.496)	(0.424)	(0.288)	(0.486)	(0.413)	(0.281)
TradMarket	0.193	0.436**	0.425***	0.215	0.436**	0.425***	0.172	0.387	0.334*
	(0.291)	(0.215)	(0.155)	(0.239)	(0.204)	(0.139)	(0.330)	(0.293)	(0.201)
ModMarket	0.316	0.199	0.335*	0.306	0.199	0.335*	0.411	0.153	0.354**
	(0.374)	(0.244)	(0.188)	(0.300)	(0.257)	(0.174)	(0.286)	(0.244)	(0.166)
Gender									
Income	−0.368	−0.095	−0.281*	−0.393	−0.095	−0.281*	−0.325	−0.063	−0.209
	(0.243)	(0.226)	(0.148)	(0.253)	(0.216)	(0.147)	(0.269)	(0.236)	(0.164)
Workload	0.681**	−0.221	0.225	0.724***	−0.221	0.225	0.775*	−0.158	0.367
	(0.312)	(0.235)	(0.144)	(0.271)	(0.232)	(0.158)	(0.407)	(0.336)	(0.232)
Child characteristics									
DDS	0.057	−0.012	0.027	0.052	−0.012	0.027	0.053	−0.006	0.033
	(0.115)	(0.102)	(0.067)	(0.115)	(0.098)	(0.067)	(0.111)	(0.095)	(0.066)
AgeChild	−0.012	0.006	−0.005	−0.012	0.006	−0.005	−0.012	0.006	−0.005
	(0.011)	(0.007)	(0.005)	(0.008)	(0.007)	(0.005)	(0.008)	(0.007)	(0.005)
MaleChild	−0.049	0.027	0.016	−0.061	0.027	0.016	−0.047	0.027	0.020
	(0.235)	(0.219)	(0.138)	(0.227)	(0.194)	(0.132)	(0.217)	(0.185)	(0.129)
Diarrhea	0.339	−0.389	−0.103	0.276	−0.389	−0.103	0.404	−0.328	0.030
	(0.363)	(0.289)	(0.198)	(0.315)	(0.270)	(0.183)	(0.387)	(0.350)	(0.242)
Maternal characteristics									
AgeMother	−0.008	0.005	−0.002	−0.008	0.005	−0.002	−0.007	0.005	−0.000
	(0.007)	(0.006)	(0.004)	(0.007)	(0.006)	(0.004)	(0.008)	(0.007)	(0.005)
EducMother	−0.092	0.117**	0.042	−0.080	0.117**	0.042	−0.091	0.118**	0.043
	(0.064)	(0.050)	(0.034)	(0.060)	(0.051)	(0.035)	(0.059)	(0.049)	(0.034)
MongMother	−0.398	0.450	0.030	−0.500	0.450*	0.030	−0.394	0.458*	0.054
	(0.297)	(0.275)	(0.183)	(0.307)	(0.262)	(0.178)	(0.302)	(0.253)	(0.176)
HtMother[a]	0.021			−0.007*			0.016		
	(0.023)			(0.004)			(0.026)		
BMIMother	−0.042	0.074**	0.027	−0.040	0.074**	0.027	−0.025	0.085	0.053
	(0.045)	(0.036)	(0.025)	(0.043)	(0.037)	(0.025)	(0.067)	(0.057)	(0.040)
Household characteristics									
LV–HA (ref: LV–LA)	0.273	−0.229	−0.016	0.293	−0.229	−0.016	0.206	−0.297	−0.149
	(0.343)	(0.310)	(0.213)	(0.367)	(0.314)	(0.214)	(0.430)	(0.376)	(0.260)
HV–LA	0.150	−0.082	0.035	0.159	−0.082	0.035	0.091	−0.149	−0.092
	(0.369)	(0.282)	(0.209)	(0.349)	(0.299)	(0.203)	(0.422)	(0.366)	(0.254)
HV-HA	0.519	−0.331	0.104	0.578*	−0.331	0.104	0.438	−0.422	−0.072
	(0.334)	(0.297)	(0.186)	(0.346)	(0.296)	(0.201)	(0.470)	(0.424)	(0.293)
Child5b	−0.127	0.077	−0.045	−0.148	0.077	−0.045	−0.127	0.078	−0.042
	(0.159)	(0.146)	(0.092)	(0.177)	(0.152)	(0.103)	(0.170)	(0.145)	(0.100)
Area	0.045	0.023	0.047	0.050	0.023	0.047	0.031	0.019	0.031
	(0.051)	(0.028)	(0.039)	(0.060)	(0.051)	(0.035)	(0.062)	(0.054)	(0.037)
NonFoodExp_pc	0.022	0.099	0.084	0.024	0.099	0.084*	0.011	0.087	0.061
	(0.086)	(0.074)	(0.060)	(0.075)	(0.064)	(0.043)	(0.085)	(0.074)	(0.051)

(Continued)

TABLE 2 | Continued

Variables	Dependent variables and estimators: Z-scores (Pooled)								
	(1) HAZ OLS	(2) WHZ OLS	(3) WAZ OLS	(4) HAZ SUR	(5) WHZ SUR	(6) WAZ SUR	(7) HAZ 3SLS	(8) WHZ 3SLS	(9) WAZ 3SLS
ImprovedToilet	0.120	−0.010	0.067	0.122	−0.010	0.067	0.154	0.008	0.113
	(0.244)	(0.240)	(0.162)	(0.249)	(0.213)	(0.144)	(0.254)	(0.217)	(0.151)
Constant	−3.748	−2.870***	−2.226***	0.422	−2.870***	−2.226***	−3.816	−3.368	−3.392**
	(3.572)	(1.007)	(0.729)	(1.398)	(1.095)	(0.744)	(3.331)	(2.289)	(1.581)
Observations	234	234	234	234	234	234	234	234	234
R^2	0.113	0.120	0.147	0.106	0.120	0.147	0.101	0.112	0.067
Adjusted R^2	0.020	0.033	0.063						
Log-likelihood	−435.400	−399.200	−308.900						
Ramsey RESET test p–value	0.706	0.047	0.125						
Linktest p–value	0.809	0.281	0.225						
Correlation matrix residuals									
HAZ-WHZ				−0.502					
HAZ–WAZ				0.421					
WHZ-WAZ				0.560					
Breusch-Pagan p–value				0.000					

*Standard errors are indicated in parentheses in the 3SLS and SUR estimators. In the OLS estimator, robust standard errors are in parentheses and clustered at the household level. We use small-sample statistics and an alternate divisor in computing the covariance matrix for the equation residuals in SUR estimator. ***p < 0.01, **p < 0.05, *p < 0.1. [a]/HtMother included only in the HAZ and stunting models. Source: Vietnam Rural Household Survey (July–August 2016).*

TABLE 3 | Impact of smallholder vegetable production on HAZ, WHZ, and WAZ of sampled boys and girls.

Main variables	Dependent variables and estimators: Z-scores (Boys)								
	(1) HAZ OLS	(2) WHZ OLS	(3) WAZ OLS	(4) HAZ SUR	(5) WHZ SUR	(6) WAZ SUR	(7) HAZ 3SLS	(8) WHZ 3SLS	(9) WAZ 3SLS
VegDiversity	0.089	−0.093	−0.019	0.094	−0.093	−0.019	−0.795	0.772*	−0.046
	(0.102)	(0.076)	(0.050)	(0.094)	(0.074)	(0.052)	(0.541)	(0.449)	(0.273)
TimeMarket	1.007	−0.256	0.376	1.012	−0.256	0.376	1.001	−0.159	0.378
	(0.634)	(0.543)	(0.304)	(0.632)	(0.493)	(0.345)	(0.610)	(0.491)	(0.334)
TradMarket	0.025	0.422	0.331*	0.033	0.422	0.331*	0.975	−0.474	0.407
	(0.430)	(0.294)	(0.175)	(0.340)	(0.265)	(0.185)	(0.630)	(0.544)	(0.345)
ModMarket	−0.140	0.085	−0.021	−0.149	0.085	−0.021	0.301	−0.188	0.069
	(0.425)	(0.328)	(0.257)	(0.416)	(0.325)	(0.227)	(0.432)	(0.343)	(0.233)
	Z-scores (Girls)								
VegDiversity	−0.022	−0.024	−0.020	−0.016	−0.024	−0.020	1.134**	−1.201**	−0.198
	(0.080)	(0.092)	(0.073)	(0.111)	(0.100)	(0.065)	(0.503)	(0.492)	(0.309)
TimeMarket	−0.633	0.905	0.322	−0.529	0.905	0.322	−0.273	0.553	0.264
	(0.870)	(0.725)	(0.411)	(0.871)	(0.781)	(0.506)	(0.834)	(0.749)	(0.486)
TradMarket	0.156	0.392	0.396	0.230	0.392	0.396*	−0.250	0.905**	0.498**
	(0.424)	(0.355)	(0.255)	(0.384)	(0.344)	(0.223)	(0.406)	(0.381)	(0.246)
ModMarket	0.648	0.246	0.593**	0.679	0.246	0.593**	1.115**	−0.245	0.487*
	(0.546)	(0.334)	(0.261)	(0.490)	(0.440)	(0.285)	(0.473)	(0.430)	(0.278)

*The full models are in the supplemental online materials **(Supplementary Tables 3A,B)**. Standard errors are indicated in parentheses in the 3SLS and SUR estimators. In the OLS estimator, robust standard errors are in parentheses and clustered at the household level. We use small-sample statistics and an alternate divisor in computing the covariance matrix for the equation residuals in SUR estimator. ***p < 0.01, **p < 0.05, *p < 0.1. a/Wasting for boys not available due to convergence failure (small number of observations). Source: Vietnam Rural Household Survey (July-August 2016).*

TABLE 4 | Impact of smallholder vegetable production on the prevalence of stunting, wasting, and underweight of pooled sample.

	Dependent variables and estimators: Prevalence of (Pooled)								
Variables	**(1) Stunting Logit**	**(2) Wasting Logit**	**(3) Underwt Logit**	**(4) Stunting SUR**	**(5) Wasting SUR**	**(6) Underwt SUR**	**(7) Stunting 3SLS**	**(8) Wasting 3SLS**	**(9) Underwt 3SLS**
Main variables of interest									
VegDiversity	−0.014	−0.005	0.006	−0.017	−0.003	0.006	0.150	−0.057	0.172*
	(0.019)	(0.011)	(0.016)	(0.020)	(0.012)	(0.018)	(0.111)	(0.065)	(0.103)
TimeMarket	−0.000	0.035	−0.114	0.003	0.022	−0.114	0.022	0.018	−0.101
	(0.141)	(0.071)	(0.115)	(0.145)	(0.085)	(0.131)	(0.142)	(0.083)	(0.128)
TradMarket	−0.010	−0.052	−0.078	−0.007	−0.041	−0.079	−0.089	−0.023	−0.205**
	(0.071)	(0.042)	(0.060)	(0.070)	(0.041)	(0.063)	(0.098)	(0.059)	(0.093)
ModMarket	−0.133	−0.033	−0.121	−0.133	−0.038	−0.115	−0.139*	−0.037	−0.115
	(0.084)	(0.047)	(0.080)	(0.087)	(0.052)	(0.079)	(0.083)	(0.049)	(0.075)
Gender									
Income	0.070	−0.095**	0.052	0.075	−0.100**	0.058	0.131	−0.124**	0.119
	(0.068)	(0.040)	(0.062)	(0.074)	(0.043)	(0.067)	(0.083)	(0.048)	(0.079)
Workload	−0.117	0.073*	−0.122	−0.131	0.085*	−0.111	0.015	0.042	0.023
	(0.072)	(0.038)	(0.075)	(0.080)	(0.047)	(0.072)	(0.124)	(0.069)	(0.111)
Child characteristics									
DDS	−0.037	0.009	0.007	−0.038	−0.002	0.010	−0.033	−0.003	0.019
	(0.032)	(0.018)	(0.027)	(0.033)	(0.020)	(0.030)	(0.034)	(0.020)	(0.032)
AgeChild	0.001	−0.003**	−0.002	0.001	−0.003**	−0.002	0.001	−0.003**	−0.002
	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
MaleChild	0.023	−0.074*	−0.043	0.024	−0.057	−0.042	0.022	−0.057	−0.038
	(0.063)	(0.043)	(0.059)	(0.066)	(0.039)	(0.060)	(0.068)	(0.038)	(0.062)
Diarrhea	−0.100	0.140***	0.052	−0.097	0.172***	0.057	0.002	0.132*	0.186
	(0.087)	(0.043)	(0.073)	(0.093)	(0.054)	(0.084)	(0.119)	(0.072)	(0.116)
Maternal characteristics									
AgeMother	0.004**	−0.001	0.001	0.004*	−0.001	0.001	0.005**	−0.002	0.003
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
EducMother	0.019	−0.018*	−0.015	0.017	−0.021**	−0.016	0.024	−0.021**	−0.014
	(0.018)	(0.009)	(0.015)	(0.018)	(0.010)	(0.016)	(0.018)	(0.010)	(0.017)
MongMother	0.057	−0.111**	0.078	0.077	−0.115**	0.075	0.059	−0.122**	0.094
	(0.087)	(0.048)	(0.080)	(0.092)	(0.053)	(0.081)	(0.094)	(0.052)	(0.085)
HtMother[a]	−0.010			−0.006			−0.017**		
	(0.006)			(0.006)			(0.008)		
BMIMother	0.012	−0.015**	−0.008	0.011	−0.012	−0.008	0.035*	−0.020*	0.016
	(0.012)	(0.007)	(0.011)	(0.013)	(0.007)	(0.011)	(0.021)	(0.012)	(0.019)
Household characteristics									
LV-HA (ref: LV-LA)	−0.060	0.072	0.010	−0.070	0.035	0.010	−0.186	0.079	−0.111
	(0.100)	(0.062)	(0.106)	(0.107)	(0.063)	(0.097)	(0.132)	(0.077)	(0.125)
HV-LA	−0.050	0.006	0.059	−0.053	0.019	0.070	−0.170	0.059	−0.053
	(0.104)	(0.052)	(0.088)	(0.102)	(0.060)	(0.093)	(0.130)	(0.075)	(0.121)
HV–HA	−0.187*	0.043	−0.005	−0.209**	0.047	−0.003	−0.351**	0.103	−0.169
	(0.095)	(0.050)	(0.095)	(0.102)	(0.059)	(0.092)	(0.144)	(0.087)	(0.140)
Child5b	0.034	−0.037	−0.006	0.036	−0.034	−0.006	0.031	−0.035	−0.003
	(0.051)	(0.032)	(0.039)	(0.052)	(0.030)	(0.047)	(0.053)	(0.030)	(0.049)
Area	−0.008	−0.005	0.002	−0.011	0.001	0.002	−0.022	0.005	−0.011
	(0.015)	(0.012)	(0.013)	(0.017)	(0.010)	(0.016)	(0.019)	(0.011)	(0.018)
NonFoodExp_pc	0.009	−0.091**	−0.009	0.010	−0.019	−0.007	−0.012	−0.012	−0.030
	(0.021)	(0.046)	(0.029)	(0.022)	(0.013)	(0.020)	(0.026)	(0.015)	(0.025)

(Continued)

TABLE 4 | Continued

Variables	Dependent variables and estimators: Prevalence of (Pooled)								
	(1) Stunting Logit	(2) Wasting Logit	(3) Underwt Logit	(4) Stunting SUR	(5) Wasting SUR	(6) Underwt SUR	(7) Stunting 3SLS	(8) Wasting 3SLS	(9) Underwt 3SLS
ImprovedToilet	−0.001	−0.001	0.019	0.001	0.005	0.018	0.042	−0.010	0.057
	(0.072)	(0.039)	(0.065)	(0.072)	(0.043)	(0.066)	(0.079)	(0.045)	(0.073)
Constant	6.288	8.223***	0.054	1.263	0.765***	0.448	1.793*	1.125**	−0.614
	(4.954)	(2.874)	(1.854)	(0.943)	(0.220)	(0.339)	(1.036)	(0.468)	(0.749)
Observations	234	234	234	234	234	234	234	234	234
R^2				0.124	0.158	0.064	−0.157	0.070	−0.305
Pseudo R^2	0.099	0.280	0.061						
Log-likelihood	−139.600	−52.520	−121.000						
χ^2	32.310	50.300	15.180						
Linktest p-value	0.468	0.053	0.745						

*Underwt, "Underweight". Standard errors are indicated in parentheses in the 3SLS and SUR estimators. In the Logit estimator, marginal effects are shown with robust standard errors in parentheses clustered at the household level. We use small-sample statistics and an alternate divisor in computing the covariance matrix for the equation residuals in SUR estimator. ***p < 0.01, **p < 0.05, *p < 0.1. a/HtMother included only in the HAZ and stunting models. Source: Vietnam Rural Household Survey (July–August 2016).*

TABLE 5 | Impact of smallholder vegetable production on the prevalence of stunting, wasting, and underweight of sampled boys and girls.

Main variables	Dependent variable and estimator: Prevalence of (Boys)								
	(1) Stunting Logit	(2) Wasting Logit[a]	(3) Underwt Logit	(4) Stunting SUR	(5) Wasting SUR	(6) Underwt SUR	(7) Stunting 3SLS	(8) Wasting 3SLS	(9) Underwt 3SLS
VegDiversity	−0.045*		0.029	−0.051*	0.004	0.033	0.437**	−0.211**	0.311**
	(0.024)		(0.019)	(0.029)	(0.014)	(0.026)	(0.185)	(0.089)	(0.157)
TimeMarket	−0.035		−0.362**	−0.028	−0.001	−0.198	−0.012	−0.029	−0.182
	(0.175)		(0.169)	(0.195)	(0.092)	(0.174)	(0.190)	(0.093)	(0.170)
TradMarket	0.016		−0.123	0.017	−0.125**	−0.113	−0.483**	0.088	−0.439**
	(0.097)		(0.087)	(0.105)	(0.050)	(0.094)	(0.208)	(0.106)	(0.190)
ModMarket	−0.086		0.094	−0.091	0.066	0.003	−0.297**	0.130**	−0.110
	(0.106)		(0.123)	(0.128)	(0.061)	(0.115)	(0.135)	(0.065)	(0.119)
	Prevalence of (Girls)								
VegDiversity	0.009	−0.017	−0.033	0.008	−0.014	−0.034	0.117	0.131	0.228*
	(0.028)	(0.016)	(0.026)	(0.031)	(0.020)	(0.028)	(0.138)	(0.096)	(0.137)
TimeMarket	0.040	−0.098	−0.069	0.027	−0.100	−0.072	0.082	−0.057	0.008
	(0.219)	(0.132)	(0.172)	(0.244)	(0.156)	(0.219)	(0.234)	(0.148)	(0.211)
TradMarket	0.014	0.064	−0.031	0.014	0.052	−0.028	0.043	−0.035	−0.152
	(0.107)	(0.062)	(0.090)	(0.109)	(0.069)	(0.097)	(0.114)	(0.075)	(0.107)
ModMarket	−0.167		−0.237**	−0.159	−0.176**	−0.188	−0.079	−0.120	−0.069
	(0.124)		(0.108)	(0.137)	(0.088)	(0.123)	(0.133)	(0.085)	(0.121)

*Underwt, "Underweight". Full models are in the supplemental online materials **(Supplementary Tables 5A,B)**. Standard errors are indicated in parentheses in the 3SLS and SUR estimators. In the Logit estimator, marginal effects are shown with robust standard errors in parentheses clustered at the household level. We use small-sample statistics and an alternate divisor in computing the covariance matrix for the equation residuals in SUR estimator. ***p < 0.01, **p < 0.05, *p < 0.1. a/Wasting for boys not available due to convergence failure (small number of observations). Source: Vietnam Rural Household Survey (July–August 2016).*

initially hypothesized. *TradMarket* and *ModMarket* are strongly associated with a reduced probability of a boy being stunted (Panel 7, $p < 0.05$). However, *ModMarket* also leads to a higher prevalence of *wasting* ($p < 0.05$) but this association requires further validation because the number of observations of wasted boys is only six percent.

This strengthens the finding that additional income gained from market participation may improve child nutrition outcomes. It also highlights that by simply selling to traditional channels rather than not selling, there is a strong and positive link with a reduced probability of being underweight.

Other Factors Associated With HAZ/Stunting and WHZ/Wasting Outcomes

Other covariates are found to be significantly associated with *WHZ/wasting* but not with *HAZ/stunting*. We speculate that the underlying determinants of nutrition, such as wealth, education, maternal care, and disease and sanitation, are significantly attenuated for *HAZ/stunting* when younger children (6–23 months) are combined with older children (24–59 months). With *WHZ/wasting*, the opposite effect is observed due to the inclusion of older children (Alderman and Headey, 2018). In this study, we did not separate by age group due to the small sample size.

HAZ

Only *Workload* is positively associated with *HAZ* (**Table 2**, Panel 7). The association is robust across different estimation techniques. It especially impacts girls[12] (1.604 SD increase, $p < 0.05$), a finding similar to previous studies (Ruel et al., 1999; Abate and Belachew, 2017). Most rural households operate as a family farming system, wherein farm operation is primarily dependent on the family's manual labor and the use of animals (Tran, 2003; Ye and Pan, 2016). To balance their agricultural obligations and their maternal and caring roles, mothers carry their babies on their backs while working in the fields. Further research is required to tease out the quality of childcare practices in the target locations because our results indicate that, in addition to income gains from modern market participation, maternal care also significantly impacts the linear growth of girls and their future offspring (Walker et al., 2015).

Stunting

Maternal height (*HtMother*) and the geographic stratum *HV-HA* are important covariates for *stunting*. *HtMother* is associated with a lower probability of *stunting* ($p < 0.05$), although the effect size is small. The association is true for both boys and girls supporting findings of other studies (e.g., Prendergast and Humphrey, 2014), which found association between stunted mothers and their children having increased likelihood of stunting. Maternal height did not have a significant effect on children's *HAZ*, which could suggest that other external factors, aside from the genetic predisposition, come into play; for instance, if women of reproductive age have access to adequate health and nutrition, and health care (De Onis and Branca, 2016). Boys in *HV-HA* have lower prevalence of *stunting* compared to those in the *LV-LA* areas[13]. This result shows that higher altitude does not imply higher incidence of stunting, and higher vegetable density per capita may have additional advantages compared with lower vegetable density per capita. Predictors that magnify the probability of *stunting* are *AgeMother* and *BMIMother* (**Table 4**, Panel 7). However, the effect sizes are small and the association (*BMIMother*) is marginal.

WHZ

Overall, *EducMother* ($p < 0.05$) and *MongMother* ($p < 0.10$) are positively associated with *WHZ*. Further, for both boys and girls, *NonFoodExp_pc* is also positively associated with *WHZ*, indicating that household income matters (Martorell and Zongrone, 2012). For boys, *WHZ* improves as they get older (*AgeChild*, $p < 0.05$). These results are robust, but the effect sizes are small. *BMIMother* also positively affects boys' *WHZ*, although marginally. Considering geographic location, boys in the *HV-HA* stratum are associated with lower *WHZ* ($p < 0.10$) than those in the *LV-LA* stratum. For girls, *Area*, another indication of household wealth, positively but marginally affects *WHZ* ($p < 0.10$), while *Income*, *Workload* and *Diarrhea* negatively affect *WHZ*. These relationships are at the 1- and 5-percent levels of significance. The negative association between *Diarrhea* and *WHZ* is especially robust in different estimation techniques. However, the impact of the two women's empowerment variables (*Income* and *Workload*) on *WHZ* is negative and highly significant at the 1- and 5-percent levels. Nonetheless, while *Workload* negatively affects *WHZ* (short-term undernutrition), it has a larger positive effect on *HAZ* (long-term undernutrition).

Wasting

The results resonate with our findings in *WHZ*, where maternal education (*EducMother*) and ethnicity (*MongMother*) positively reduce the probability of *wasting*, in addition to *Income* and *AgeChild* ($p < 0.05$). However, the effect sizes of *AgeChild* and *EducMother* are relatively small. Among boys, the probability of *wasting* is reduced via *Income*, *AgeChild* and *BMIMother*. The probability of *wasting* among girls is strongly reduced via *NonFoodExp_pc* ($p < 0.05$). *Diarrhea*, as previously shown, increases the probability of *wasting*, especially among girls, as does *Workload*. For *Workload*, reduced workload means more time spent at home and less time spent helping in productive agricultural activities. This may negatively affect the household's meager disposable income, and therefore alter the amount, quantity, composition and quality of food purchased and consumed by these children (Carletto et al., 2015). The prevalence is increased by *LV-HA* and *HV-HA* areas in relation to *LV-LA*, which indicates that elevation may affect the increased incidence of *wasting* among boys. As previously mentioned, these results for boys require further validation due to the small number of observations.

These results indicate that wealth (*NonFoodExp_pc*) and maternal education are important for addressing short-term undernutrition consistent with other studies (Frost et al., 2005; Martorell and Zongrone, 2012; Makate and Makate, 2017). However, addressing short-term undernutrition differs for boys and girls due to preferential treatment given to sons among these ethnic minority communities (Jones et al., 2014). Mothers allocate more health-promoting resources and childcare time to sons, thereby negatively affecting girls' nutritional status in

[12]Full models with all control variables used are in the supplemental online materials (**Supplementary Tables 3A,B**).

[13]Full models with all control variables used are in the supplemental online materials (**Supplementary Tables 5A,B**).

the short-term (Barcellos et al., 2014). This might also explain the positive, but marginal relationship, between maternal BMI and boy's WHZ. The incidence of diarrhea severely affects girls' WHZ/wasting, and thus requires future research to identify its determinants.

SUMMARY, DISCUSSION, AND LIMITATIONS

This cross-sectional study analyzed 234 children aged 6–60 months and has shown how smallholder vegetable production may lead to positive nutritional outcomes through improving a child's linear growth (HAZ) and weight (WHZ and WAZ), and reducing the prevalence of stunting, wasting, and underweight. To our knowledge, this is the first study that assesses the contribution of smallholder vegetable production on child nutrition among ethnic minority communities. Our results are broadly consistent with the results of other studies showing how agriculture in general, and specific crop/livestock in particular, can lead to improved children's nutrition (e.g., Hoddinott et al., 2015; Kumar et al., 2015; Malapit et al., 2015; Shively and Sununtnasuk, 2015). However, the impact on children's nutrition varies for each of the smallholder vegetable production indicators and by gender, controlling for other covariates in the econometric models.

About 80 percent of smallholder households in the province mainly grow vegetables for home consumption. For these subsistence farmers, diversifying their vegetable production has an added advantage. It has benefits in that it improves boys' WHZ and girls' HAZ. However, its health benefits are mixed because it leads to a higher prevalence of stunting and underweight among boys. It may significantly improve girls' HAZ, but no significant association has been found to mitigate the stunting outcome.

Our results suggest that smallholder vegetable production has a significant indirect effect on children's nutrition via market participation. Among boys, market participation is associated with a lower probability of stunting and underweight. Our results also indicate that other covariates, such as maternal education and diarrhea incidence, are significantly associated with the short-term nutritional outcomes (WHZ and wasting).

What do these results imply for smallholder vegetable producers in Lao Cai province, Vietnam? Our results point at issues that require further study to determine whether there is causal relationship between these variables, and not just a correlation. If that is the case, there is a need to create and/or improve existing market linkages between smallholder vegetable producers and markets. The type of linkage will depend on the specific conditions in each locality: farmer-to-trader linkage, farmer-to-retailer linkage, or creation of farmer groups or cooperatives. While markets present opportunities for rural farmers to increase their livelihoods, it can also lead to higher transaction costs if they are not suitably adapted to the locality, thus inducing some households to opt out of market participation (Fackler and Goodwin, 2001; Renkow et al., 2004). Road infrastructure investments or better information about market opportunities and prices, can also likely improve children's nutritional outcomes in the long-term, particularly with respect to reduced stunting.

In addition to providing income-generating opportunities for these households, future interventions could also incorporate the following factors that are strongly associated with child nutritional outcomes. The first is to promote education among the ethnic minority communities because higher maternal educational attainment increases the allocative efficiency of health production. Maternal education is a significant predictor of a child's disease incidence, as well as the ability to report or seek medical care at community health centers when their children are suffering from diarrhea (Rheinlander et al., 2010). The odds of a child being reported slightly sick is 25 percent higher if the mother has some primary schooling rather than being illiterate (Teerawichitchainan and Phillips, 2008). Education also provides access to more information on balanced diets and nutrition, which translates to better nutritional knowledge and better feeding practices (Makate and Makate, 2017), and therefore higher demand for diverse foods (Moon et al., 2002) and healthy food choices (Variyam et al., 1998). One study in Vietnam (Nguyen et al., 2013) found that children whose mothers had reached high school education were 1.7 times more likely to achieve the minimum dietary diversity than those mothers who did not go to school. Among Mong food preparers, improving their nutritional knowledge, by providing them information about healthy eating, could be included in the design of any future health-promoting intervention. Young children from ethnic minority communities (Thai-Muong, Tay-Nung, E De-Mnong) suffer lower dietary diversity compared to the children of Kinh mothers since ethnic minority mothers give their young children fewer legumes and nuts, dairy products, flesh foods, and vitamin-A rich fruits and vegetables (Nguyen et al., 2016). While the aim is not to impose change on their ethnic heritage, nutritional education could highlight the benefits of diversified diets, which can translate to better child nutritional outcomes. Nutritional education can increase children's dietary diversity, as shown by previous studies in Cambodia, Malawi, and Western Kenya (Waswa et al., 2015; Reinbott et al., 2016; Kuchenbecker et al., 2017). When dietary diversity is promoted through nutritional education, it can be easily integrated into the local knowledge (Powell et al., 2017). Further research on the quality of maternal care-giving practices is also encouraged because it has important implications for the improvement of girls' HAZ, WHZ, and wasting.

Furthermore, the country has had numerous policy actions aimed at improving safe water supply and constructing sanitation facilities in rural areas. However, uptake of the water and sanitation facilities among ethnic minority communities has been slow since the current hygiene and sanitation policies fail to understand the local cultural and social factors that guide their sanitation behaviors (Rheinlander et al., 2010). Therefore, sanitation solutions that are in line with the local priorities and hygiene perceptions, and are designed appropriately to suit their living conditions, could ensure the effectiveness of future hygiene-promotion strategies (Rheinlander et al., 2010).

The observed gender differences with respect to health inequality in our sample may be due to either preferential treatment toward one gender or be biological in nature. In Sub-Saharan Africa, the preferential treatment of girls gives rise to their slight anthropometric advantage over boys (Svedberg, 1990). However, biologically, boys are more vulnerable to stunting than girls (Wamani et al., 2007). There may be other contributing factor(s) to this that our survey was not able to capture.

In the broader context, the above results highlight similar findings of previous studies in Vietnam where significant reductions in child undernutrition can be driven by improvements in household income, maternal education, hygiene, and health and nutrition services (Kien et al., 2016; Nguyen et al., 2017; Beal et al., 2019; Harris et al., 2021). Research has shown that hard infrastructure alone, e.g., provision of roads or sanitation facilities, must be coupled with adequate levels of soft infrastructure investments (human capital and innovation) to maximize impact on the target beneficiaries. This is crucial given the deeper structural issues underpinning nutritional inequities among ethnic minority communities in Vietnam. For instance, how do we encourage the ethnic minorities to adopt vegetable diversification or participate in markets while taking into account their resistance to state intervention in favor of their traditional indigenous knowledge either due to cultural and language barriers, mistrust due to state territorialization and fragmentation of their traditional social geography, or that the changes brought about by these interventions are too drastic and undermine their traditional way of life (Bonnin and Turner, 2012; Harris et al., 2021)?

Currently, their agricultural productivity remains low and they are resistant to change. They use local varieties with limited inputs that result in lower yields. They also tend to operate on subsistence farming and lack the entrepreneurial impetus, with mismatched interests and abilities on the production of high-value industrial crops. In terms of market engagement, they use their cultural networks and avoid the Kinh-dominated markets (Minh, 2019; World Bank, 2019). All these may have to be taken into account when tackling child undernutrition.

An enabling environment may also be needed to support these socioeconomic drivers. Harris et al. (2021) has identified three crucial areas to achieve stunting reduction in ethnic minority communities. These are: (a) adaptation of a differentiated socioeconomic policy for ethnic minorities that highlight the specific needs and preferences of these communities; (b) prioritization of nutrition funding and capacity building for provinces with high minority populations to overcome the barriers for service delivery; and (c) engagement of more national and international civil societies that champion the inclusion of ethnic minorities into the nutrition policymaking process.

This study has several limitations that need to be considered. Firstly, it is based on cross-sectional data that inhibits us to capture variations in household behavior over time. Secondly, the sampled households are from districts with high geographic concentrations of ethnic minority communities and are thus not comparable to previous child undernutrition studies using the Vietnam Nutrition Surveillance System (Beal et al., 2019) or Vietnam Multiple Indicator Cluster Survey (Kien et al., 2016; Harris et al., 2021), where ethnic minorities are underrepresented. Also, other variables, like child immunization, vitamin A supplementation, maternal breastfeeding practices, or economic shocks, are not included in the analysis due to data limitations. The small number of observations also prevents us from conducting disaggregated analysis by age group, which would have been more meaningful since various underlying determinants of children's nutrition outcomes are age-sensitive (Alderman and Headey, 2018). Despite these limitations, these results do show that improved child nutrition outcomes in Lao Cai province can be achieved by improving livelihoods via smallholder vegetable production and market participation. Further research is encouraged to ascertain the causal relationships using more observations and longitudinal or panel data.

In conclusion, child undernutrition continues to be a public health concern in Lao Cai province, where stunting rate remains one of the highest in the country. This study presents evidence that smallholder vegetable production can be an alternative and sustainable solution to address child undernutrition, especially among ethnic minority communities in remote areas. It can be replicated in other geographic locations with high concentrations of disadvantaged groups to assist in the design and implementation of nutritional and health promotion policies using the available resource as part of the solution.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Low Risk Human Research Ethics Review Group (Faculty of the Arts and Faculty of the Professions), Compliance and Integrity, Research Services, The University of Adelaide (H-2015-159). Written informed consent was obtained from all individual respondents in the study.

AUTHOR CONTRIBUTIONS

CG involved in the study design, performed primary data collection, data encoding, data cleaning, data analysis, data interpretation, and wrote and revised the manuscript. WU guided study design and data collection, supervised data analysis and data interpretation, provided intellectual input, and edited the manuscript. AP guided study design and data collection, supervised data analysis and data interpretation, and edited the manuscript. SN guided study design and data collection, contributed in data interpretation, and edited the manuscript. DZ supervised data analysis and data interpretation and edited the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.900625/full#supplementary-material

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